Remarks

In view of the above amendments and the following remarks, reconsideration of the outstanding office action is respectfully requested.

With the miniaturization and increasing power of microelectronics, heat dissipation has become critical to the performance, reliability and further miniaturization of microelectronics. Heat dissipation from microelectronics is most commonly performed by thermal conduction. For this purpose, a heat sink, which is a material of high thermal conductivity, is commonly used. In order for the heat sink to be well utilized, the thermal contact between the heat sink and the heat source (e.g., a substrate with a semiconductor chip on it) should be good.

A thermal fluid or paste is commonly applied at the interface to enhance the thermal contact. The fluid or paste is a material that has high conformability so that it can conform to the surface topography of the mating surfaces, thereby avoiding air gaps (which are thermally insulating) at the interface. The fluid or paste must be highly spreadable, so that the thickness of the paste after application is very thin (just enough to fill the valleys in the surface topography of the mating surfaces). Preferably the fluid or paste is thermally conductive as well. Although much attention has been given to the development of heat sink materials, relatively little attention has been given to the development of thermal fluids or pastes.

The most common thermal fluid is mineral oil. As a fluid, it is highly conformable and spreadable, but it has a low thermal conductivity. The most common thermal paste is silicone filled with thermally conductive particles. Due to the filler, it is relatively high in thermal conductivity, but it suffers from poor conformability and poor spreadability. Thermal fluids and pastes of previous work are not as effective as solder (applied when it is molten), but they do not require heating, which is required for the use of solder.

Due to its excellent heat transfer characteristics and as it is relatively inexpensive, boron nitride is commonly used as a filler for thermal interface materials. Unfortunately, however, it suffers from the disadvantage that it degrades when exposed to humidity. When placed in a humid environment, hygroscopic impurities (boric oxide) within the compound absorb atmospheric water, which then reacts with the boron nitride to form boric acid. Being hygroscopic, the boric acid absorbs further water, thereby accelerating the

degradation of the boron nitride and diminishing its heat removing capabilities, which ultimately leads to failure of the device. Published PCT Application WO 01/21393 is specifically directed to this problem and describes a moisture resistant, thermally conductive material that includes thermally conductive filler particles, preferably boron nitride, that are coated with a hydrophobic compound, preferably a silicone compound such as a siloxane. The hydrophobic compound-coated filler particles are joined together with a binder, and account for between 5 and 70 vol.% of the material.

Organic vehicles are commonly used as the suspending medium for dispersed inorganic particles in pastes. An organic vehicle system may consist of a solvent (such as butyl ether) and a solute (such as ethyl cellulose), which serves to enhance the dispersion and suspension. Ethyl cellulose has the further advantage of its slight conductivity.

Another organic vehicle is polyethylene glycol (PEG), a polymer of low molecular weight (400 amu), which is different from silicone in its low viscosity. By using PEG in conjunction with boron nitride particles as a thermal paste between copper disks, a thermal contact conductance of 1.9×10^5 W/m^2·°C has been attained. This value is higher than that obtained by using a thermal paste involving silicone and boron nitride powder (1.1×10^5 W/m^2·°C), but is lower than that obtained by using solder, applied in the molten state (2.1×10^5 /m^2·°C). In fact, all thermal pastes previously reported are inferior to solder in providing high thermal contact conductance.

Carbon black is a very fine particulate form of elemental carbon, consisting of typically spherical particles, which in turn come together to form porous agglomerates. Carbon black is produced either by incomplete combustion or thermal decomposition of a hydrocarbon feedstock. Types of carbon black include soot, lamp black (typical particle size 50-100 nm), channel black (typical particle size 10-30 nm), furnace black (typical particle size 10-80 nm), thermal black (typical particle size 150-500 nm), and acetylene black (typical particle size 35-70 nm).

Carbon black is used as a low-cost electrically conductive filler in polymers. Due to its relatively low thermal conductivity, however, carbon black has not been reported as a filler for thermally conductive pastes. Most commonly, it is used as a reinforcement in rubber.

In addition, carbon black is used in electrochemical electrodes, inks, lubricants, fuels, and pigments.

The present invention is directed to overcoming these and other deficiencies in the art relating to thermal interface materials.

The specification is amended to correct a typographical error. Therefore, no new matter has been entered by this amendment.

Applicant affirms the election of Group II (i.e., claims 22-24) with traverse. Applicant submits that the claims of the present application are closely related and, therefore, require common areas of search and consideration. Since no benefit is derived from imposing this restriction requirement, it should be withdrawn in its entirety.

The rejection of claim 22 under 35 U.S.C. § 103(a) for obviousness over U.S. Patent No. 5,098,609 to Iruvanti et al. ("Iruvanti") is respectfully traversed.

Iruvanti teaches a paste having a thermally conducting solid filler, a nonaqueous electrically resistive liquid carrier, and a stabilizing dispersant. Solid fillers include highly thermally conducting metallic or ceramic (e.g., diamond) fillers. In contrast, amended claim 22 of the present application relates to a thermally conductive interface material made of a thermally conductive paste containing porous agglomerates of carbon black dispersed in a paste-forming vehicle, where the paste, when compressed between a heat source and a heat sink, forms a thermally conductive interface material. Support for the amendment to claim 22 is found in the application as filed at claims 1-2; page 5, lines 4-6; page 12, line 22 to page 13, line 3; Table 1, and Figure 2.

Iruvanti fails to teach or suggest porous agglomerates of carbon black in a thermally conductive interface material. Diamond particles are not porous agglomerates of carbon black. In particular, carbon black has "relatively low thermal conductivity" (page 3, lines 28-30), whereas Iruvanti teaches that diamond particles are "highly thermally conducting." Moreover, porous agglomerates of carbon black are spreadable, whereas diamond particles are not (page 10, lines 26-27). This important property of porous agglomerates of carbon black over diamond particles is believed to be the reason for superior performance of the thermally conductive interface material of the present invention over thermally conductive interface materials containing other solid fillers, such as diamond particles (page 10, lines 20-30).

Because Iruvanti fails to teach or suggest a thermally conductive interface material containing porous agglomerates of carbon black, it cannot be said to render the claimed invention obvious. Therefore, the rejection of claim 22 under 35 U.S.C. § 103(a) for obviousness over Iruvanti is improper and should be withdrawn.

The rejection of claims 23-24 under 35 U.S.C. § 103(a) for obviousness over Iruvanti, in view of U.S. Patent No. 5,545,679 to Bollinger, Jr. et al. ("Bollinger") is rendered moot in light of the above cancellation of claims 23-24.

Amended claim 22 now incorporates limitations of claims 23-24. Applicant asserts that the combination of Iruvanti and Bollinger would not have rendered obvious the subject matter of amended claim 22.

Bollinger is cited as teaching a positive temperature coefficient ("PTC") conductive polymer that is used in circuit devices. The polymer includes graphite and/or carbon black and a thermosetting polyester resin. The thermosetting polyester can be polyethylene glycol fumerate.

Applicant submits that the teachings of Iruvanti and Bollinger cannot be properly combined, because Bollinger is not analogous art. The Federal Circuit has set forth a two-pronged test to determine whether a reference constitutes analogous art. *In re Clay,* 966 F.2d 656, 658-59, 23 USPQ2d 1058, 1060-61 (Fed. Cir. 1992). The test considers:

> (1) Whether the art is from the same field of endeavor, regardless of the problem addressed, and (2) if the reference is not within the field of the inventor's endeavor, whether the reference still is reasonably pertinent to the particular problem with which the inventor is involved.

Id. In this case, both Iruvanti and the present invention relate to thermally conductive interface materials. Bollinger, on the other hand, relates to PTC current limiting compositions. In particular, Bollinger teaches thermosetting polyester resin combined with conductive particles of graphite and/or carbon black as a current limiting composition. Bollinger clearly does not relate to the same field of endeavor (of thermally conductive interface materials). Further, Bollinger is not reasonably pertinent to the particular problem solved by the present invention (a thermally conductive interface material in the form of a paste formed from porous agglomerates of carbon black dispersed in a paste-forming vehicle). As taught by the present application, carbon black has been used in electrochemical electrodes and as a low-cost electrically conductive filler in polymers (page 3, lines 26-27). However, because carbon black has a relatively low thermal conductivity, it has not been reported as a filler for thermally conductive pastes (page 3, lines 28-30). There is no teaching or suggestion in Bollinger that carbon black can be used in a thermally conductive interface material as in the present invention. Furthermore, given the relatively low thermal

conductivity of carbon black noted above, it would not have been obvious to a person of skill in the art to make a thermally conductive interface material made of a thermally conductive paste containing porous agglomerates of carbon black dispersed in a paste-forming vehicle, where the paste forms a thermally conductive interface material when compressed between a heat source and a heat sink. For the foregoing reasons, Iruvanti and Bollinger are not properly combinable.

Iruvanti and Bollinger would also not have rendered obvious the subject matter of new claims 111-124, which depend from amended claim 22, for at least the same reasons as set forth above with respect to amended claim 22. Support for new claims 111-124 is found in the application as filed at page 6, line 30 to page 9, line 22.

In view of the foregoing, applicant submits that this case is in condition for allowance and such allowance is earnestly solicited.

Respectfully submitted,

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